APPENDIX B
FAILURE RATE DATA

TO THE

INDEPENDENT RISK ANALYSIS
(APPENDIX C1)

SUBJECT:	SYSTEM / COMPONENT / STEP:	ASSUMPTION / VALUE:	BASIS:	REFERENCE:
IDN001. Improper filling of LNG Cargo Tank	Initiating event frequency for the improper filling of an LNG tank that is out of service.	Annual failure frequency: 0.04/yr * 1.4E-3 = 5.5E-5.	In the 25 year design life of the FSRU BHP Billiton does not expect to ever have to isolate the tank for entry. Conservatively assume one tank entry for any cause in the life of the FSRU. 0.04/yr. An estimate of improper filling is derived from failure of work process controls (isolation, lock out – tag out) conditioned on the cargo tank entry frequency. 1.4E-3 energy isolation failures/energy isolation performed.	Confidential client(s) data.
IDN002. Improper filling of LNG Cargo Tank	Tank unmanned and failure to detect the improper LNG loading of an out of service tank.	Assume the tank will be unmanned half an hour every 24 hours. 0.02	NA	NA
IDN003. Improper filling of LNG Cargo Tank	Loss of 2-way radio communication causing a failure to detect the improper LNG loading.	Assume the loss of 2-way radios inside the tank would occur 1 in every 100 attempts. 0.01	NA	NA
IDN004. Improper filling of LNG Cargo Tank	Personnel inside tank incapacitated and unable to communicate the improper LNG loading.	0.5	50% chance that LNG released in a tank will cause the personnel in the tank to be incapacitated in such a way that they would be unable to communicate with topsides personnel.	NA
IDN005. Improper filling of LNG Cargo Tank	Topsides tank watchman unavailable and failing to detect the improper LNG loading.	0.02	1 in 50 chances that the topsides watchman will not be available for communication.	NA

SUBJECT:	SYSTEM / COMPONENT / STEP:	ASSUMPTION / VALUE:	BASIS:	REFERENCE:
IDN006. Improper filling of LNG Cargo Tank	Failure to detect LNG in tank.	Fault tree calculations show the overall probability of failing to detect LNG inside a gas free tank to 0.55	The fault tree shown in Figure 5.2 provides logic for the failure to detect LNG in tank.	NA
IDN007. Improper filling of LNG Cargo Tank	Failure to shutdown the LNG loading in sufficient time.	2.4E-02	Table 5-3. System-oriented Human Error Probability Data Sample. Value used: Mean Human Error Probability (HEP), Error of omission, for ESALS (emergency safety and activator logic system) Operates, location: control room operator	Gertman, David I., and Harold S. Blackman. 1994. *Human Reliability & Safety Analysis Data Handbook*. New York: John Wiley and Sons, Inc.
IDN008. Improper filling of LNG Cargo Tank	Ignition of the LNG liquid or vapors inside the tank.	Assume no forced ventilation inside tank. 0.25	Based on P_{max} of the Ignition Model on page 81.	DNV Technica Ltd. 1992. *Offshore Hazard and Risk Analysis Toolkit Reference Manual*. London: Lynton House
IDN009. Improper filling of LNG Cargo Tank	Failure of the LNG cargo tank causing adjacent tank escalation.	NA	NA	NA

SUBJECT:	SYSTEM / COMPONENT / STEP:	ASSUMPTION / VALUE:	BASIS:	REFERENCE:
IDN010. Extreme weather during loading operations	Initiating event frequency for extreme weather to occur during loading operations.	Joint probability from the conditional and marginal probabilities. 0.014 * 4.7E-02 = 6.6E-4	BHPB will shutdown loading operations for wave heights greater than 2.8m. NOAA data buoy (46025) shows that wave heights at Cabrillo Port will be less than 2.8m 98.6% of the time, hence 0.014 /yr exceedance. Table 5-36. Source Categories of Action Consequence, …II.6 Value used: Violate procedure and devise own formula 4.7E-02	www.noaa.gov (weather data buoy # 46025). Gertman, David I., and Harold S. Blackman. 1994. *Human Reliability & Safety Analysis Data Handbook*. New York: John Wiley and Sons, Inc.
IDN011. Extreme weather during loading operations	Failure of emergency disconnect of loading arms.	2.3E-4 per transfer	Data shows a 'Snaptite' coupling failure rate (while the transfer is in progress) of 2.3E-5 due to collision while loading. Taking the collision probability data out leaves us with a failure rate of 2.3E-4.	Health Safety Commission, © 1991, *Major Hazard Aspects of the Transport of Dangerous Substances,* London (page 259)
IDN012. Extreme weather during loading operations	Ignition of released LNG from emergency disconnect or loading arm failure.	Assume no forced ventilation inside tank. 0.25	Based on P_{max} of the Ignition Model on page 81.	DNV Technica Ltd. 1992. *Offshore Hazard and Risk Analysis Toolkit Reference Manual*. London: Lynton House
IDN013. Loading arm leak during normal loading operation	Initiating event frequency for loading arm leak during normal loading operation.	3.85E-03	Based on the referenced value for a medium leak (50mm) in the loading arms.	Gas Research Institute. 1990. *Reduction of LNG Operator Error and Equipment Failure Rates.*
IDN014. Loading arm leak during normal loading operation	Failure of leak detection from loading arms.	0.05	Expert Judgment, assume 5% failure rate for detection of loading arm leak.	NA

SUBJECT:	SYSTEM / COMPONENT / STEP:	ASSUMPTION / VALUE:	BASIS:	REFERENCE:
IDN015. Loading arm leak during normal loading operation	Failure of automatic isolation/shutdown of loading operation.	3.0E-2	Assume system designed to SIL-2 Safety Integrity Level, as defined in IEC Guideline	*Recommended Guidelines for the Application of IEC-61508 and IEC-61511 in the Petroleum Activities on the Norwegian Continental Shelf* © 2001. (Page 37 - Table 8.1)
IDN016. Loading arm leak during normal loading operation	Failure of manual ESD of loading operation.	2.4E-02	Table 5-3. System-oriented Human Error Probability Data Sample. Value used: Mean Human Error Probability (HEP), Error of omission, for ESALS (emergency safety and activator logic system) Operates, location: control room operator	Gertman, David I., and Harold S. Blackman. 1994. Human Reliability & Safety Analysis Data Handbook. New York: John Wiley and Sons, Inc.
IDN017. Loading arm leak during normal loading operation	Ignition of released LNG from loading arm leak.	Assume no forced ventilation inside tank. 0.25	Based on P_{max} of the Ignition Model on page 81.	DNV Technica Ltd. 1992. *Offshore Hazard and Risk Analysis Toolkit Reference Manual*. London: Lynton House
IDN018. LNG tank leak into adjacent void space	Initiating event frequency for LNG tank leak into adjacent void space.	2.7E-08	There are no recorded failure of Moss-type LNG spheres. Failure rates for equipment items where no failures have occurred can be calculated by assuming that the failure can be described by a Binomial distribution with the appropriate number of consecutive successes. LPG service was used as surrogate.	Sooby, W., and J. M. Tolchard, 1994. *Estimation of Cold Failure Frequency of LPG Tanks in Europe,* LPG Engineering and Safety Group, Shell International Petroleum Company Limited.

SUBJECT:	SYSTEM / COMPONENT / STEP:	ASSUMPTION / VALUE:	BASIS:	REFERENCE:
IDN019. Powered collision of merchant vessels using coastal traffic lanes	Number of transits on traffic separation scheme (TSS) per year	10,010 transits per year.	VTS LA/LB statistics for 2001, 2002 and 2003.	U.S. Coast Guard Vessel Traffic Service Los Angeles/Long Beach. 2002-2004. Excel spreadsheet with 2002-2004 vessel traffic data for VTS LA/LB. Forwarded by OMC William Hooker, USCG May 20, 2004.
IDN020. Powered collision of merchant vessels using coastal traffic lanes	Probability of hitting the FSRU while on course, P_1.	6.1 E-6	Rayleigh distribution function skewed to one side with a mode of 0.5 nautical miles and a FSRU located at 2.5 nautical miles.	NA
IDN021. Powered collision of merchant vessels using coastal traffic lanes	Failure of the merchant vessel steering control, P_2.	2.0E-4	NA	DNV, Concept Safety Assessment of LNG Floating, Storage & Regasification Unit (FSRU), Final Report March 14, 2003, Project No. 230-11749
IDN022. Powered collision of merchant vessels using coastal traffic lanes	Failure of the collision vessel to recover from its errant state to an FSRU warning.	0.67	NA	DNV, Concept Safety Assessment of LNG Floating, Storage & Regasification Unit (FSRU), Final Report March 14, 2003, Project No. 230-11749
IDN023. Drifting collision of merchant vessels using coastal traffic lanes	Total traffic in box vessels per year.	5,005	VTS LA/LB statistics for 2001, 2002 and 2003.	Vessel Traffic System Los Angeles/Long Beach annual reports 2001, 2002 and 2003

SUBJECT:	SYSTEM / COMPONENT / STEP:	ASSUMPTION / VALUE:	BASIS:	REFERENCE:
IDN024. Drifting collision of merchant vessels using coastal traffic lanes	Probability of break down in the box, P_b.	Value depends on the probability of break down per hour P_{bh}, the length of the box L and the speed of drifting S. $P_b = P_{bh} \times L / S$ If P_{bh} = 2.0E-5/hr, L = 2.7 nautical miles, S = 3 knots, then P_b = 1.8E-5	NA	DNV, Concept Safety Assessment of LNG Floating, Storage & Regasification Unit (FSRU), Final Report March 14, 2003, Project No. 230-11749
IDN025. Drifting collision of merchant vessels using coastal traffic lanes	Probability of wind, P_w.	Value depends on the annual wind rose data around the FSRU. From North West, P_w equals 0.11	NA	AMOG Report – Metocean study for BHP application
IDN026. Drifting collision of merchant vessels using coastal traffic lanes	Collision diameter divided by perpendicular length to wind direction	Value depends on the collision diameter and the perpendicular length to wind direction for each box. If collision diameter is equal to 0.15 and the perpendicular length to wind direction for a specific box is 1.6 nautical miles, then collision diameter to perpendicular length to wind direction will be 9.4E-2.	NA	DNV, Concept Safety Assessment of LNG Floating, Storage & Regasification Unit (FSRU), Final Report March 14, 2003, Project No. 230-11749
IDN027. Powered collision of commercial vessels calling at Port Hueneme	Number of transits with direction to Port Hueneme per year	Value depends on the traffic on each route followed by the vessel on its way to Port Hueneme.	NA	Telephone conversations of Port Hueneme officials with John Pierce, Ecology and Environment, Inc., Houston, Texas

SUBJECT:	SYSTEM / COMPONENT / STEP:	ASSUMPTION / VALUE:	BASIS:	REFERENCE:
IDN028. Powered collision of commercial vessels calling at Port Hueneme	Probability of hitting the FSRU while on course, P_1.	Value depends on the distance to the FSRU	Assumed that vessels follow a straight route between islands or avoid areas in the direction of Port Hueneme. Applied normal distribution function with a standard deviation of 0.5 nautical miles for each route.	NA
IDN029. Powered collision of commercial vessels calling at Port Hueneme	Failure of the merchant vessel steering control, P_2.	2.0E-4	NA	DNV, Concept Safety Assessment of LNG Floating, Storage & Regasification Unit (FSRU), Final Report March 14, 2003, Project No. 230-11749
IDN030. Powered collision of commercial vessels calling at Port Hueneme	Failure of the collision vessel to recover from its errant state to an FSRU warning.	0.67	NA	DNV, Concept Safety Assessment of LNG Floating, Storage & Regasification Unit (FSRU), Final Report March 14, 2003, Project No. 230-11749
IDN031. Drifting collision of commercial vessels calling at Port Hueneme	Total traffic in box vessels per year.	Value depends on the traffic on each route followed by the vessel on its way to Port Hueneme.	NA	Telephone conversations of Port Hueneme officials with John Pierce, Ecology and Environment, Inc., Houston, Texas
IDN032. Drifting collision of commercial vessels calling at Port Hueneme	Probability of break down in the box, P_b.	Value depends on the probability of break down per hour P_{bh}, the length of the box L and the speed of drifting S. $P_b = P_{bh} \times L / S$ If P_{bh} = 2.0E-5/hr, L = 2.7 nautical miles, S = 3 knots, then P_b = 1.8E-5	NA	DNV, Concept Safety Assessment of LNG Floating, Storage & Regasification Unit (FSRU), Final Report March 14, 2003, Project No. 230-11749

SUBJECT:	SYSTEM / COMPONENT / STEP:	ASSUMPTION / VALUE:	BASIS:	REFERENCE:
IDN033. Drifting collision of commercial vessels calling at Port Hueneme	Probability of wind, P_w.	Value depends on the annual wind rose data around the FSRU. For instance it the wind blows from North West, P_w equals 0.11	NA	AMOG Report – Metocean study for BHP application.
IDN034. Drifting collision of commercial vessels calling at Port Hueneme	Collision diameter divided by perpendicular length to wind direction	Value depends on the collision diameter and the perpendicular length to wind direction for each box. If collision diameter is equal to 0.15 and the perpendicular length to wind direction for a specific box is 1.6 nautical miles, then collision diameter to perpendicular length to wind direction will be 9.4E-2.	NA	DNV, Concept Safety Assessment of LNG Floating, Storage & Regasification Unit (FSRU), Final Report March 14, 2003, Project No. 230-11749
IDN035. Powered collision of crude oil carriers calling at El Segundo	Number of transits with direction to El Segundo per year	Value depends on the traffic on each route followed by the vessel on its way to El Segundo	NA	Telephone conversation of Mooring Master at El Segundo Refinery with John Pierce, Ecology and Environment, Inc., Houston, Texas
IDN036. Powered collision of crude oil carriers calling at El Segundo	Probability of hitting the FSRU while on course, P_1.	Value depends on the distance to the FSRU.	Assumed that vessels follow a straight route between islands or avoided areas with direction to El Segundo. Applied normal distribution function with a standard deviation of 0.5 nautical miles for each route.	NA

SUBJECT:	SYSTEM / COMPONENT / STEP:	ASSUMPTION / VALUE:	BASIS:	REFERENCE:
IDN037. Powered collision of crude oil carriers calling at El Segundo	Failure of the merchant vessel steering control, P_2.	2.0E-4	NA	DNV, Concept Safety Assessment of LNG Floating, Storage & Regasification Unit (FSRU), Final Report March 14, 2003, Project No. 230-11749
IDN038. Powered collision of crude oil carriers calling at El Segundo	Failure of the collision vessel to recover from its errant state to an FSRU warning.	0.67	NA	DNV, Concept Safety Assessment of LNG Floating, Storage & Regasification Unit (FSRU), Final Report March 14, 2003, Project No. 230-11749
IDN039. Drifting collision of crude oil carriers calling at El Segundo.	Total traffic in box vessels per year.	Value depends on the traffic on each route followed by the vessel on its way to El Segundo Refinery.	NA	Telephone conversation of Mooring Master at El Segundo Refinery with John Pierce, Ecology and Environment, Inc., Houston, Texas
IDN040. Drifting collision of crude oil carriers calling at El Segundo.	Probability of break down in the box, P_b.	Value depends on the probability of break down per hour P_{bh}, the length of the box L and the speed of drifting S. $P_b = P_{bh} \times L / S$ If P_{bh} = 2.0E-5/hr, L = 2.7 nautical miles, S = 3 knots, then P_b = 1.8E-5	NA	DNV, Concept Safety Assessment of LNG Floating, Storage & Regasification Unit (FSRU), Final Report March 14, 2003, Project No. 230-11749
IDN041. Drifting collision of crude oil carriers calling at El Segundo.	Probability of wind, P_w.	Value depends on the annual wind rose data around the FSRU. For instance it the wind blows from North West, P_w equals 0.11	NA	AMOG Report – Metocean study for BHP application.

SUBJECT:	SYSTEM / COMPONENT / STEP:	ASSUMPTION / VALUE:	BASIS:	REFERENCE:
IDN042. Drifting collision of crude oil carriers calling at El Segundo.	Collision diameter divided by perpendicular length to wind direction	Value depends on the collision diameter and the perpendicular length to wind direction for each box. If collision diameter is equal to 0.15 and the perpendicular length to wind direction for a specific box is 1.6 nautical miles, then collision diameter to perpendicular length to wind direction will be 9.4E-2.	NA	DNV, Concept Safety Assessment of LNG Floating, Storage & Regasification Unit (FSRU), Final Report March 14, 2003, Project No. 230-11749
IDN043. Powered collision of navy vessels operating on the Point Mugu Sea Range	Number of transits with direction to Point Mugu Sea Range per year	Value depends on the traffic on each route followed by the vessel on its way to Point Mugu Sea Range	NA	U.S. Department of Defense, March 2002. Final Environmental Impact Statement/Overseas Environmental Impact Statement, Pt. Mugu Sea Range. Prepared by the U.S. Department of the Navy, Naval Systems Command, Naval Air Warfare Center Weapons Division, Pt. Mugu, California.
IDN044. Powered collision of navy vessels operating on the Point Mugu Sea Range	Probability of hitting the FSRU while on course, P_1.	Value depends on the distance to the FSRU.	Assumed that vessels follow a straight route between islands or avoid areas in the direction to Point Mugu Sea Range. Applied normal distribution function with a standard deviation of 0.5 nautical miles for each route.	NA

SUBJECT:	SYSTEM / COMPONENT / STEP:	ASSUMPTION / VALUE:	BASIS:	REFERENCE:
IDN045. Powered collision of navy vessels operating on the Point Mugu Sea Range	Failure of the merchant vessel steering control, P_2.	2.0E-4	NA	DNV, Concept Safety Assessment of LNG Floating, Storage & Regasification Unit (FSRU), Final Report March 14, 2003, Project No. 230-11749
IDN046. Powered collision of navy vessels operating on the Point Mugu Sea Range	Failure of the collision vessel to recover from its errant state to an FSRU warning.	0.67	NA	DNV, Concept Safety Assessment of LNG Floating, Storage & Regasification Unit (FSRU), Final Report March 14, 2003, Project No. 230-11749
IDN047. Drifting collision of navy vessels operating on the Point Mugu Sea Range.	Total traffic in box vessels per year.	Value depends on the traffic on each route followed by the vessel on its way to Point Mugu Sea Range.	NA	U.S. Department of Defense, March 2002. Final Environmental Impact Statement/Overseas Environmental Impact Statement, Pt. Mugu Sea Range. Prepared by the U.S. Department of the Navy, Naval Systems Command, Naval Air Warfare Center Weapons Division, Pt. Mugu, California.
IDN048. Drifting collision of navy vessels operating on the Point Mugu Sea Range.	Probability of break down in the box, P_b.	Value depends on the probability of break down per hour P_{bh}, the length of the box L and the speed of drifting S. $P_b = P_{bh} \times L / S$ If P_{bh} = 2.0E-5/hr, L = 2.7 nautical miles, S = 3 knots, then P_b = 1.8E-5	NA	DNV, Concept Safety Assessment of LNG Floating, Storage & Regasification Unit (FSRU), Final Report March 14, 2003, Project No. 230-11749

SUBJECT:	SYSTEM / COMPONENT / STEP:	ASSUMPTION / VALUE:	BASIS:	REFERENCE:
IDN049. Drifting collision of navy vessels operating on the Point Mugu Sea Range.	Probability of wind, P_w.	Value depends on the annual wind rose data around the FSRU. For instance it the wind blows from North West, P_w equals 0.11	NA	AMOG Report – Metocean study for BHP application.
IDN050. Drifting collision of navy vessels operating on the Point Mugu Sea Range.	Collision diameter divided by perpendicular length to wind direction	Value depends on the collision diameter and the perpendicular length to wind direction for each box. If collision diameter is equal to 0.15 and the perpendicular length to wind direction for a specific box is 1.6 nautical miles, then collision diameter to perpendicular length to wind direction will be 9.4E-2.	NA	DNV, Concept Safety Assessment of LNG Floating, Storage & Regasification Unit (FSRU), Final Report March 14, 2003, Project No. 230-11749
IDN051. Drifting collision of LNG carriers calling at Cabrillo Port	Number of transits approaching the FSRU per year	Value depends on the traffic on each route followed by the vessel on its way to the FSRU.	NA	BHP application
IDN052. Drifting collision of LNG carriers calling at Cabrillo Port	Probability of drifting towards the FSRU, P_1.	0.01	Assumed that P1 equals to angle subtended by FSRU divided by 2 π	John Spouge. 1999. A Guide to Quantitative Risk Assessment For Offshore Installations, DNV
IDN053. Drifting collision of LNG carriers calling at Cabrillo Port	Probability of wind blowing towards the FSRU, P_2.	Value depends on the annual wind rose data around the FSRU. For instance it the wind blows from North West, P_2 equals 0.11	NA	AMOG Report – Metocean study for BHP application.

SUBJECT:	SYSTEM / COMPONENT / STEP:	ASSUMPTION / VALUE:	BASIS:	REFERENCE:
IDN054. Drifting collision of LNG carriers calling at Cabrillo Port	Probability of break down, P_3.	Value depends on the probability of break down per hour P_{bh}, the length of the box L and the speed of drifting S. $P_3 = P_{bh}$ x L /S If P_{bh} = 2.0E-5/hr, L = 2.7 nautical miles, S = 3 knots, then P_3 = 1.8E-5	NA	DNV, Concept Safety Assessment of LNG Floating, Storage & Regasification Unit (FSRU), Final Report March 14, 2003, Project No. 230-11749
IDN055. Drifting collision of supply vessels operating near Cabrillo Port	Number of transits approaching the FSRU per year	Value depends on the traffic on each route followed by the vessel on its way to the FSRU.	NA	BHP Application
IDN056. Drifting collision of supply vessels operating near Cabrillo Port	Probability of drifting towards the FSRU, P_1.	0.01	Assumed that P1 equals to angle subtended by FSRU divided by 2 π.	John Spouge. 1999. A Guide to Quantitative Risk Assessment For Offshore Installations, DNV
IDN057. Drifting collision of supply vessels operating near Cabrillo Port	Probability of wind blowing towards the FSRU, P_2.	Value depends on the annual wind rose data around the FSRU. For instance it the wind blows from North West, P_2 equals 0.11	NA	AMOG, Metocean Study for Cabrillo Port, Report No. 065 475 818, BHPB Application.
IDN058. Drifting collision of supply vessels operating near Cabrillo Port	Probability of break down, P_3.	It depends on the probability of break down per hour P_{bh}, the length of the box L and the speed of drifting S. $P_3 = P_{bh}$ x L /S If P_{bh} = 2.0E-5/hr, L = 2.7 nautical miles, S = 3 knots, then P_3 = 1.8E-5	NA	DNV, Concept Safety Assessment of LNG Floating, Storage & Regasification Unit (FSRU), Final Report March 14, 2003, Project No. 230-11749

SUBJECT:	SYSTEM / COMPONENT / STEP:	ASSUMPTION / VALUE:	BASIS:	REFERENCE:
IDN059. Collision of fishing vessels operating near Cabrillo Port	Number of fishing vessels on collision course per year	2,208 transits per year.	NA	Natural Resources Consultants, Inc. March 10, 2003, jjune@nrccorp.com. Commercial and recreational fisheries in the vicinity of a proposed pipeline near Ventura, California. (http:/www.nrccorp.com).
IDN060. Collision of fishing vessels operating near Cabrillo Port	Failure of the merchant vessel steering control, P_2.	2.0E-4	NA	DNV, Concept Safety Assessment of LNG Floating, Storage & Regasification Unit (FSRU), Final Report March 14, 2003, Project No. 230-11749
IDN061. Collision of fishing vessels operating near Cabrillo Port	Failure of the collision vessel to recover from its errant state to an FSRU warning.	0.67	NA	DNV, Concept Safety Assessment of LNG Floating, Storage & Regasification Unit (FSRU), Final Report March 14, 2003, Project No. 230-11749